In-beam Measurement of the Position Resolution of a Highly Segmented Coaxial Germanium Detector

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The next generation of gamma-ray detectors arrays, e.g. GRETINA/GRETA, will use highly segmented coaxial germanium detectors and have the new capability to give the energy and location of each gamma-ray interaction inside the detector. They will provide orders of magnitude improvement in detection sensitivity for many applications in basic and applied nuclear science. Here, we report a measurement of the position resolution for a highly segmented coaxial germanium detector obtained from an in-beam experiment. The position resolution was obtained by comparing the observed Doppler energy spread with simulation. Measurements were made with the GRETA prototype II detector: a high purity n-type coaxial germanium crystal, shaped into a regular hexagon, 9 cm long, 7 cm in diameter, and with a 10 degree taper along its length. The outer contact is electrically segmented in 36 parts: 6 angular and 6 transverse.

The experiment was performed at the LBNL 88-Inch Cyclotron. A ^{82}Se beam (~3 enA on target) bombarded a ^{12}C target (100ug/cm2 thick) at an energy of 385 MeV to produce the nucleus ^{90}Zr with a large recoil velocity (v/c = 8.7%). Our interest was to study the 2055 keV transition in ^{90}Zr. The detector was placed 90 degrees to the beam direction and at a distance of 4cm from the target in order to maximize the Doppler broadening contribution to the measured peak width, which is then directly related to the uncertainty in location of the first gamma-ray interaction. In this measurement we obtained a peak width (full width half maximum) of 14.5 keV for the 2055 keV peak in ^{90}Zr. From comparison with simulation we associate this with a position resolution σ=2 mm (RMS in 3-dimensions).

To study the contribution of different factors to the position resolution (i.e. noise, electronics threshold, number of working channels, and uncertainty in the definition of the start time of the signal shape, Δt_0), additional simulations were carried out including one factor at a time. These results are illustrated in the table, which shows, for a given condition, the FWHM of the spectral peak and the corresponding position resolution, after correcting the γ-ray energy for the position of the first interaction. Condition (A) corresponds to an ideal case where there is no source of uncertainty (beside the intrinsic energy resolution of 6.4 keV), all 36 segments are included and the peak width is 7.6 keV, corresponding to σ=0.6 mm. This provides a measure of the accuracy of the signal decomposition algorithm. In condition (B) a noise level of 5 keV (RMS) is added to the simulated data, which is the average noise measured in the GRETA prototype detector in a ``low noise" environment. The energy resolution measured in this case is 8.1 keV. In condition (C) a noise level of 13 keV is added to the simulated data; this is the noise level measured during the experiment. In this case a FWHM of 8.9 keV is obtained. Condition (D) is similar to (C) and includes the effect of a 50 keV electronic threshold. This results in a FWHM of 9.3 keV. Condition (E) is similar to (D), but now we also include the effect of removing from the analysis segment E3 and all segments in the last two layers of the detector. In this case the energy resolution is 9.9 keV. Condition (F) is similar to condition (E) with the added uncertainty that the pulse start time for the simulated data was determined in the same manner as the measured data; i.e. a leading edge time with a ~30 keV threshold. In this case a FWHM of 14.9 keV is obtained, which is to be compared with the experimental value of 14.5 keV.

These simulations indicate that in the current measurement the major source of error in determining the position of the interaction is the uncertainty in signal the start time. Algorithms are being developed to use t_0 as a fitting variable in the signal decomposition code. These algorithms, in conjunction with a common trigger for all segments, should provide a position resolution of about 1 mm RMS.

condi tion	Factors contributing to position resolution				FWHM [keV]	RMS [mm]
	noise	thresh	working chns	t_0		
A	none	none	all	perfect	7.6	0.6
B	5 keV	none	all	perfect	8.1	0.7
C	13 keV	none	all	perfect	8.9	0.9
D	13 keV	50keV	all	perfect	9.3	0.9
E	13 keV	50keV	no E3, A5-F5, A6-F6	perfect	9.9	1.1
F	13 keV	50keV	no E3, A5-F5, A6-F6	Δt_0	14.9	2.0

This work was supported under the U.S. Department of Energy contract Nos. DE-AC03-76SF00098 (LBNL), W-7405-Eng-48 (LLNL), and DE-AC05-00OR22725 (ORNL).